California Energy Commission
Energy R&D Activities:
The PIER Program

Redwoods Technology Conference
Eureka, Ca
April 30, 2004

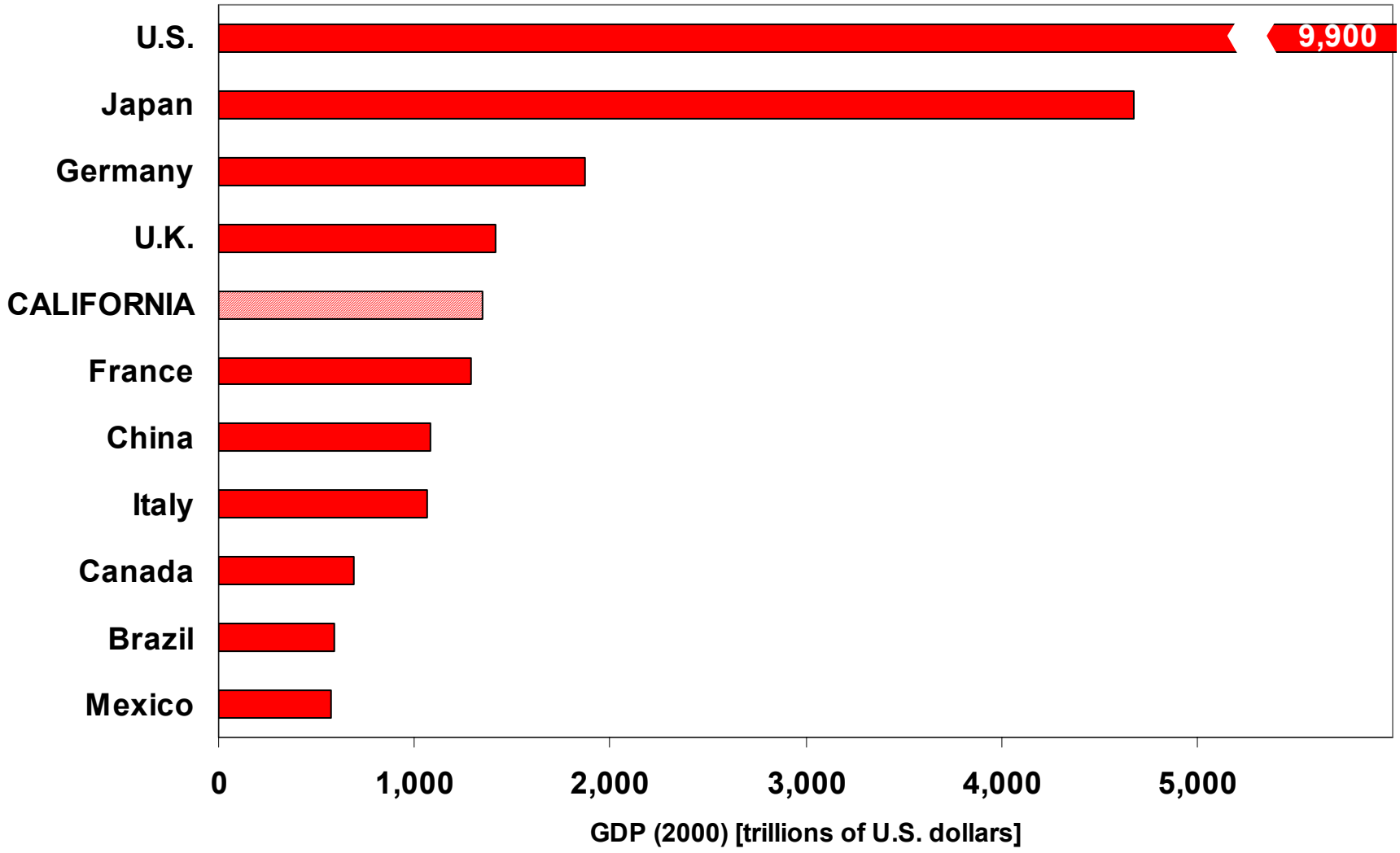
Terry Surles

PIER Program Director

Christopher Guay

Lawrence Berkeley National Laboratory

GDP (2000)


U.S.
Japan
Germany
U.K.
CALIFORNIA
France
China
Italy
Canada
Brazil
Mexico
9,900
0
1,000
2,000
3,000
4,000
5,000
GDP (2000) [trillions of U.S. dollars]

California has Established a $62M/yr Public Interest Energy Research Program (PIER)

Economy: Affordable Solutions

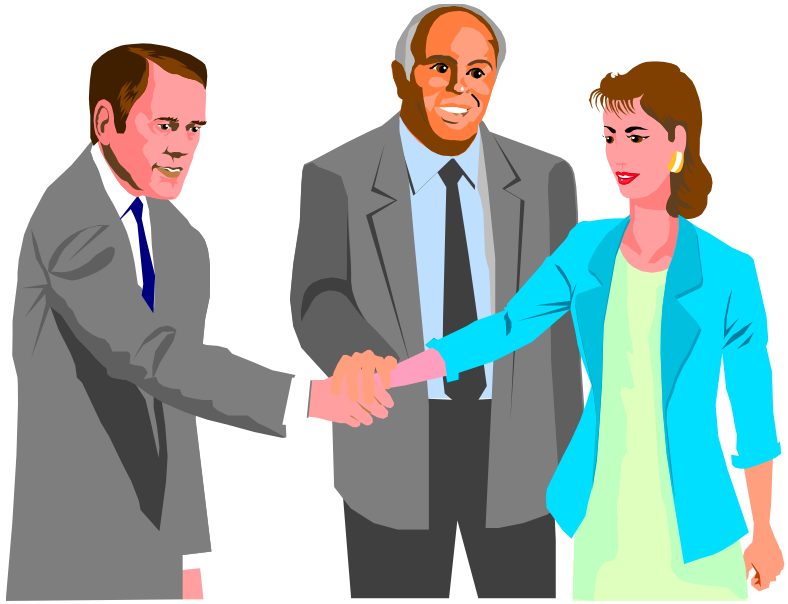
Quality: Reliable and Available

Environment: Protect and Enhance

Vision Statement

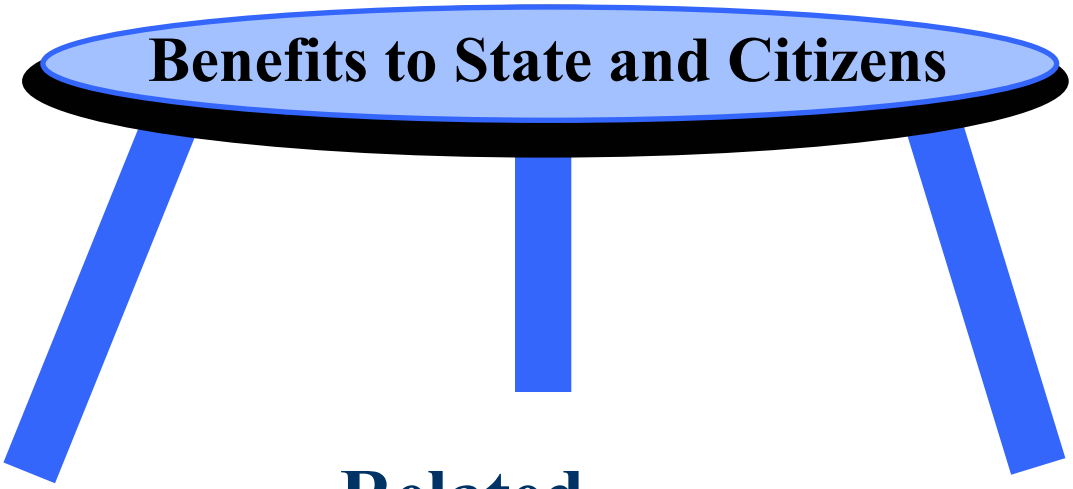
The future electrical system of California will provide a clean, abundant and affordable supply tailored to the needs of "smart", efficient customers and will be the best in the nation.

Tailored, clean, abundant, affordable supply



Smart, efficient customers

Pier Has Designed a Program to Take Advantage of Its Unique Position to Provide Benefits to the State



California Issues

Related State Activities

Collaborations

California Must be Prepared to Face the Same Issues as Others Must

- **Economics**
  - Resource Competition
  - New technology market penetration
  - Life cycle analysis
  - State/Federal Laws
- **Environment**
  - Impact of new technologies
  - Climate change
  - Sustainable practices
- **Security**
  - Peak demand/demand response
  - Infrastructure interdependencies

Energy Costs Fundamentally Affect our Overall Economy

PIER Program Ties into Synergistic State Regulatory, Incentive, and Subsidy Programs

- Buildings – Titles 20 and 24
- Renewables – Renewable portfolio standard (RPS)
- Environmentally-Preferred Advanced Generation – 2007 ARB rules on distributed generation emissions
- Energy Systems Integration –
  - CPUC/CEC initiatives in demand response/dynamic pricing
  - CAISO intermittent energy resources, transmission management tools
- Environmental – Impacts/opportunities related to RPS, state initiatives (AB 1493) in climate change
- Industrial/Ag/Water – State water issues

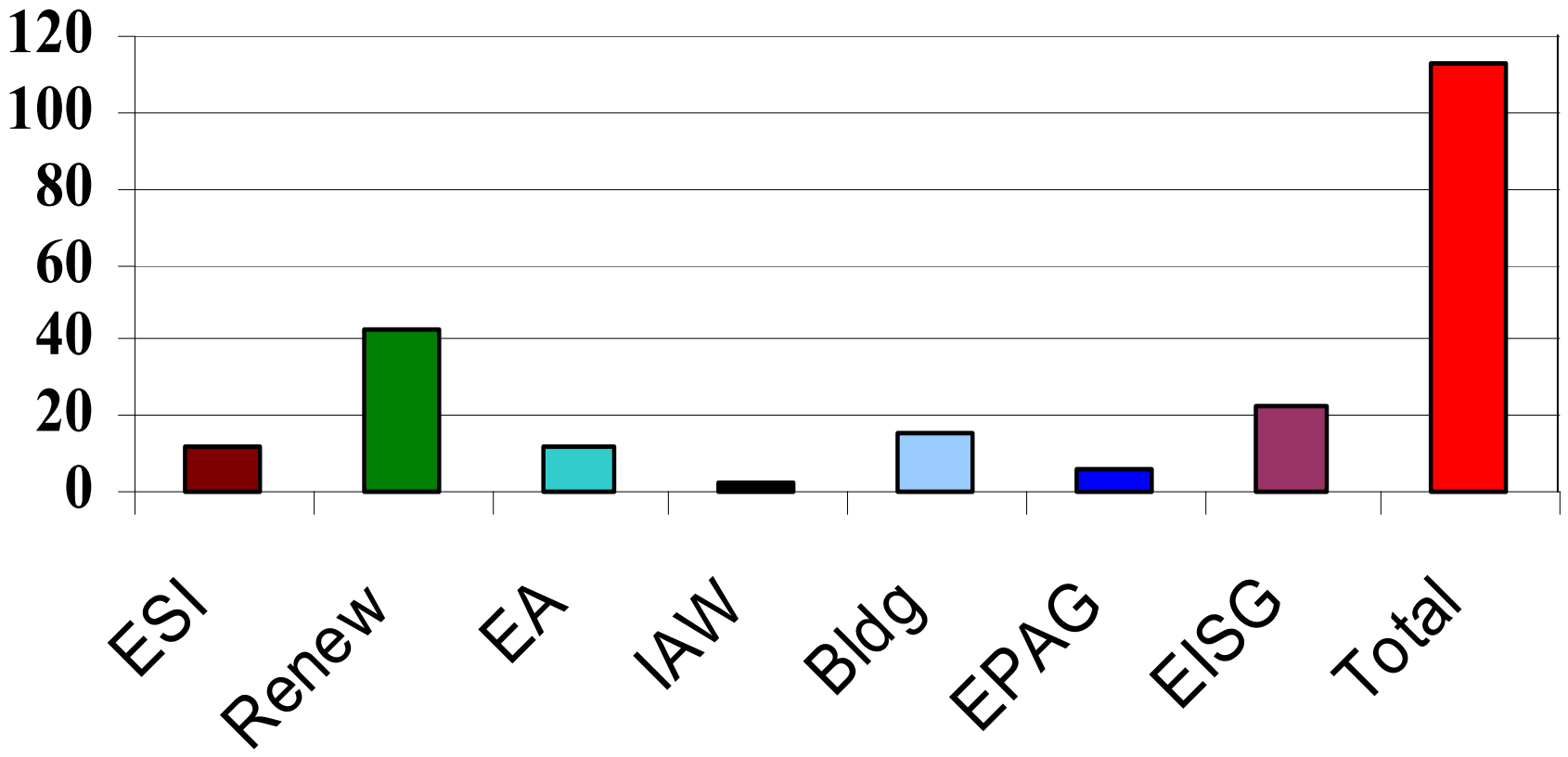
Our Success is Coupled to the Successes of Our Technology Partnerships

- **Universities** – UCOP standard contract
- **Industries** – funding, obtaining co-funding, pushing deployment
- **Federal** – Departments of Energy, Commerce, Agriculture
- **National Laboratories** – LBNL, NREL, LLNL, ORNL, NETL, SNL, ANL
- **State** – ARB, CDF, DWR, DOGGR, CFA, CPA, CPUC, DGS

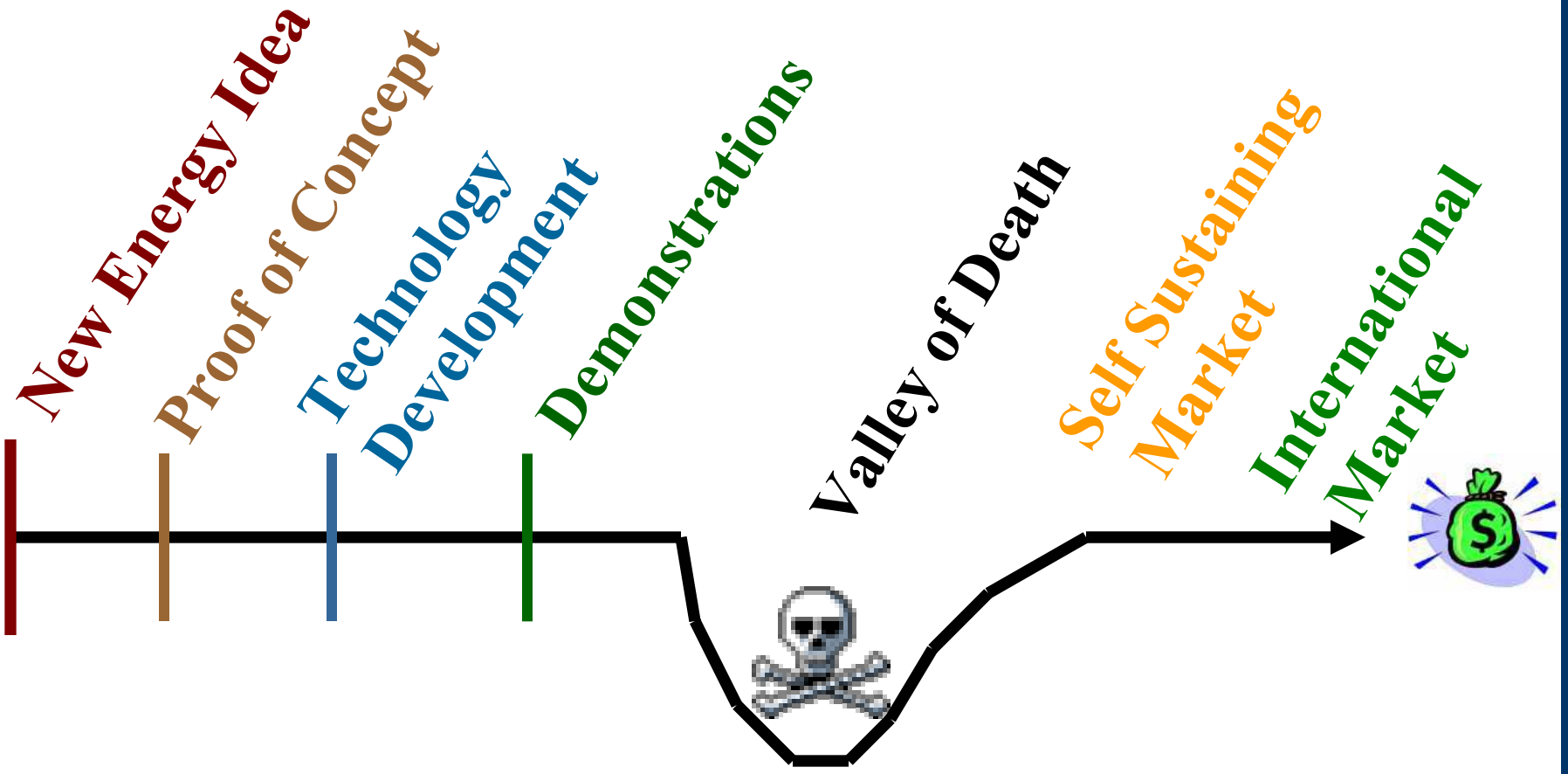
Examples of Successful Working Relationships with Industries

- Silicon valley Manufacturing Group (SVMG)
  - **Ongoing attendance at bimonthly Energy Committee meetings for setting RD&D agenda and priorities since early 2001**
- California League of Food Processors (CFLP)
  - **Formed an industry advisory group that met quarterly in 2001-2002 to set RD&D agenda and priorities**
- American Water Works Association - Research Foundation (AWWA-RF)
- Emerging Technology Coordination Council (ETCC)- a PUC-mandated coalition with CA utilities for technology deployment and coordination

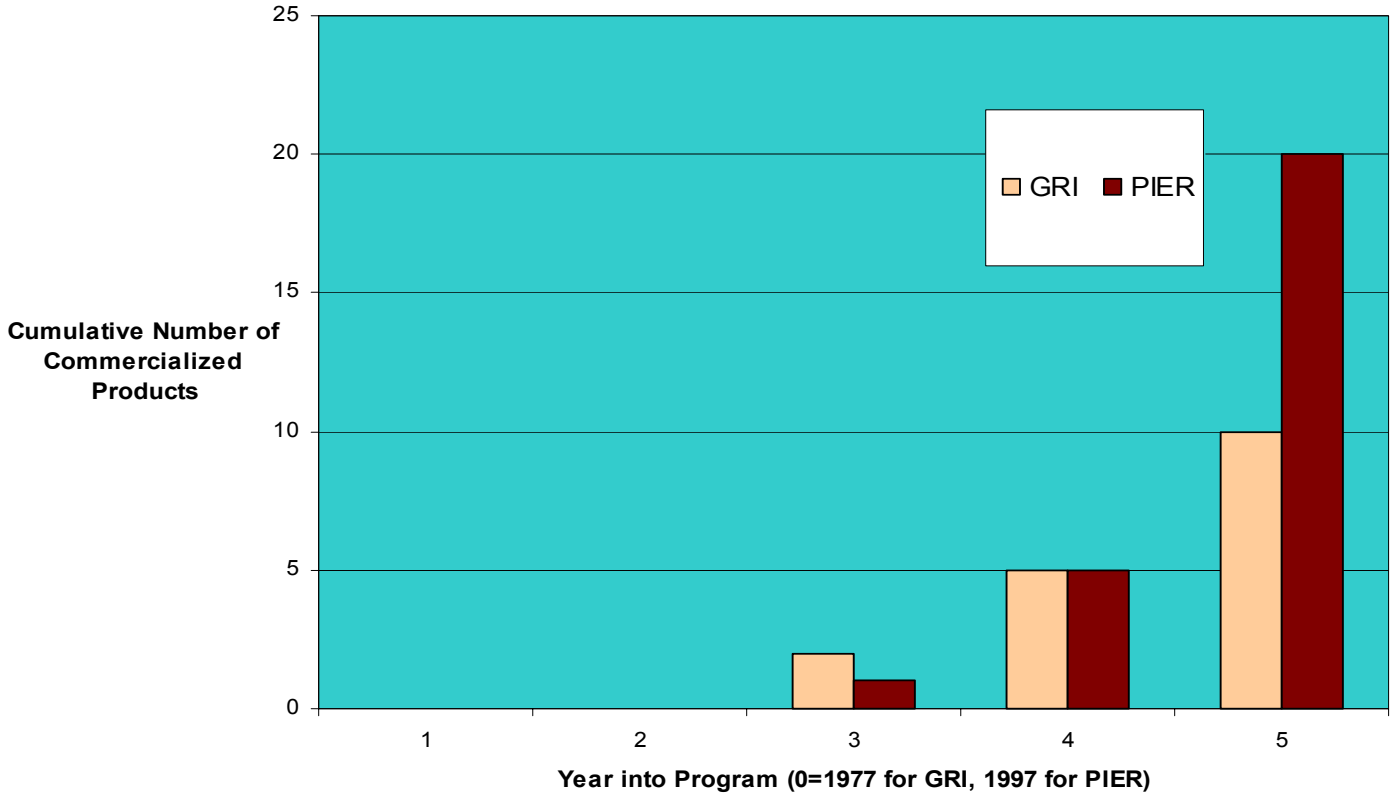
PIER has been Effective in Bringing External Funding Into State



PIER is Attempting to Bridge the Valley of Death: NREL Growth Forum, Incubators, SB 1038



The Early Current Return on Investment Between $2 and $5 Per dollar Spent is Excellent for This Stage of Any R&D Program



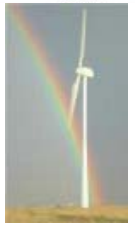
This analysis does not estimate intrinsic public benefits arising from reduced energy use and an improved environment.

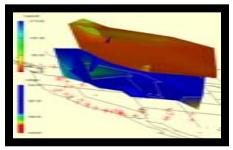
CEC/PIER is Already Providing a Stream of Products Consistent with the California Energy Action Plan (CEAP)

CEAP Goal	PIER Issue
Optimize efficiency, Reduce demand	Reduce per capita energy use
Ensure power supply meet RPS	Meet RPS
Upgrade T&D structure	T&D System must be reliable and congestion-free
Promote DG	Peak demand reduction Low emissions DG Reliable, affordable DG
Ensure reliable supply of NG	Meet marketplace needs

Products







The Berkeley Lamp

Laboratory-Utility-State Partnership

green metal panel

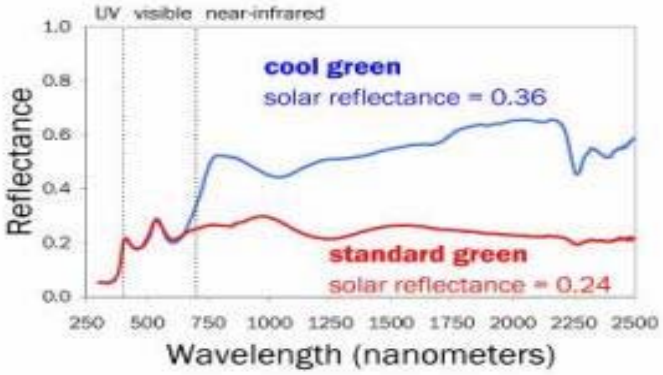
Courtesy BASF Corporation

cool

solar reflectance = 0.36
thermal emittance = 0.85
roof temp – air temp = 31°C (56°F)

standard

solar reflectance = 0.24
thermal emittance = 0.85
roof temp – air temp = 38°C (68°F)



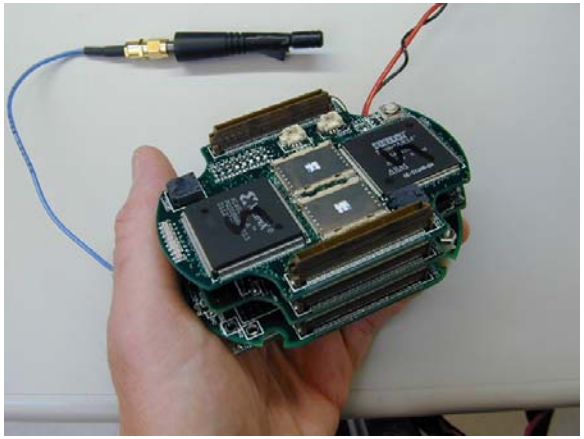
Colored Cool Roof Project

- Available now:
  - Standing seam
  - Clay tile

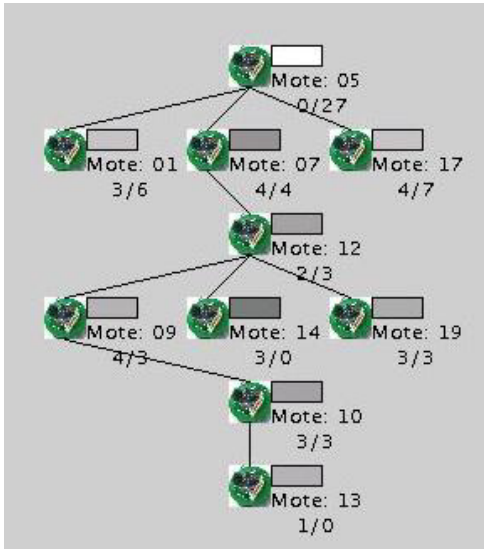
- In development
  - Concrete tile
  - Composition

EAGLELITE
Golden Eagle #199

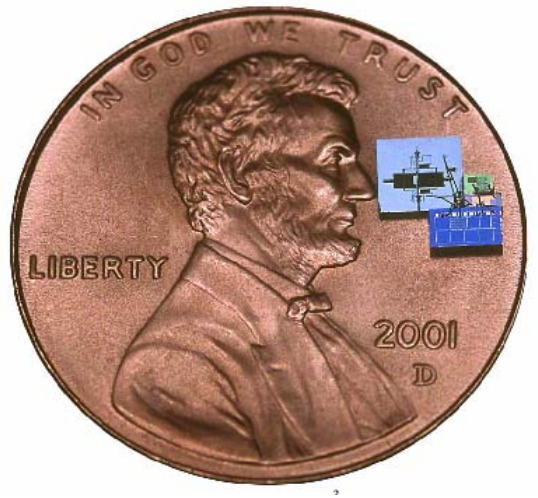
UC Berkeley Technologies



Pico radio
Ultra-low energy
(<5nJ/bit)
Ultra-low power
(<100 μW)

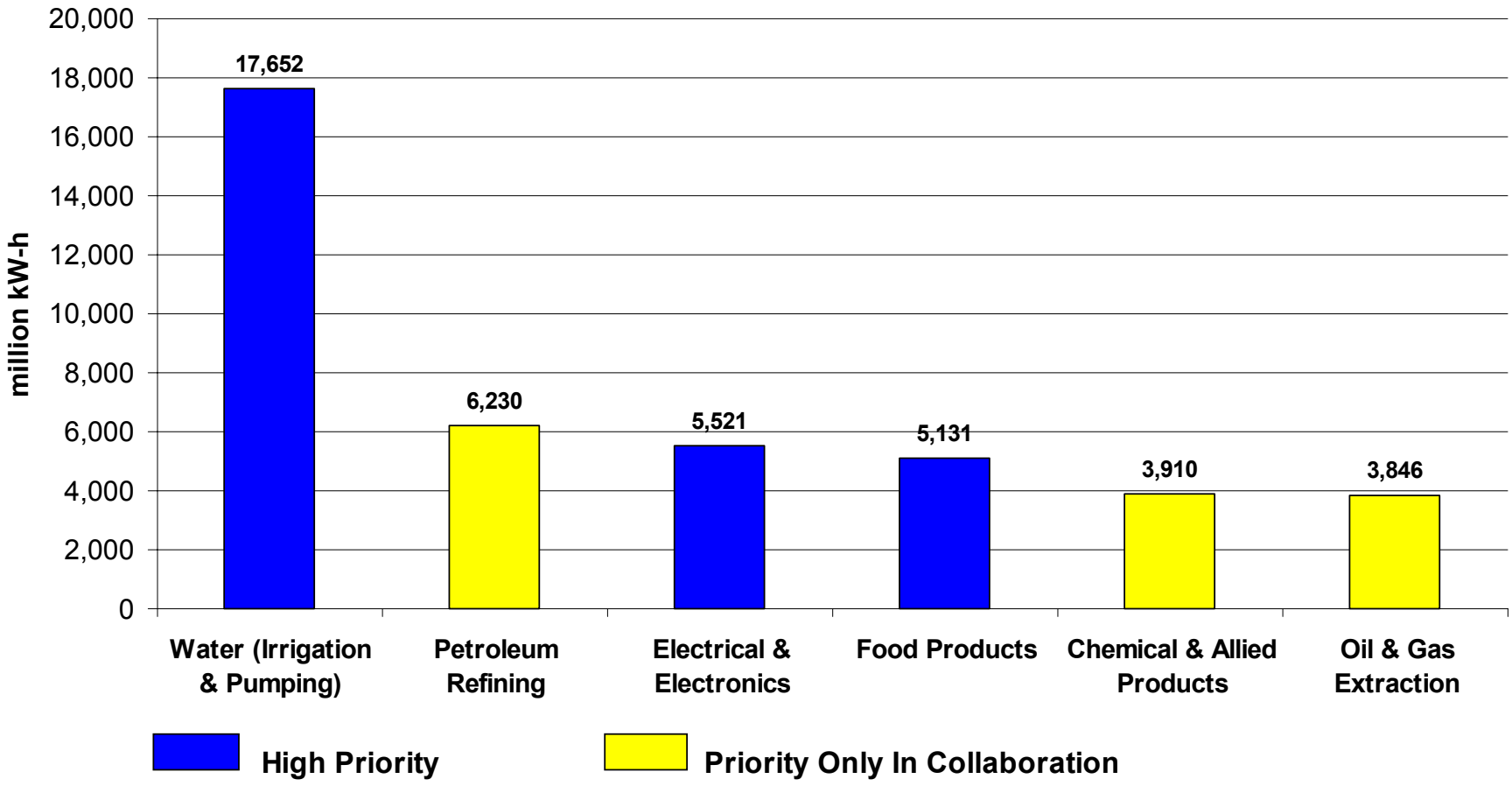


TinyOS
Event-based
operating system for
sensor networks.



Smart Dust
Ultra-small
(<1 mm^3)

Program Priority for Energy Intensive Industries that Impact the Economy, Employment and the Environment



Link in Irrigation and Electricity Use (Detail Analysis Commenced upon Tech Review Committee Suggestion)

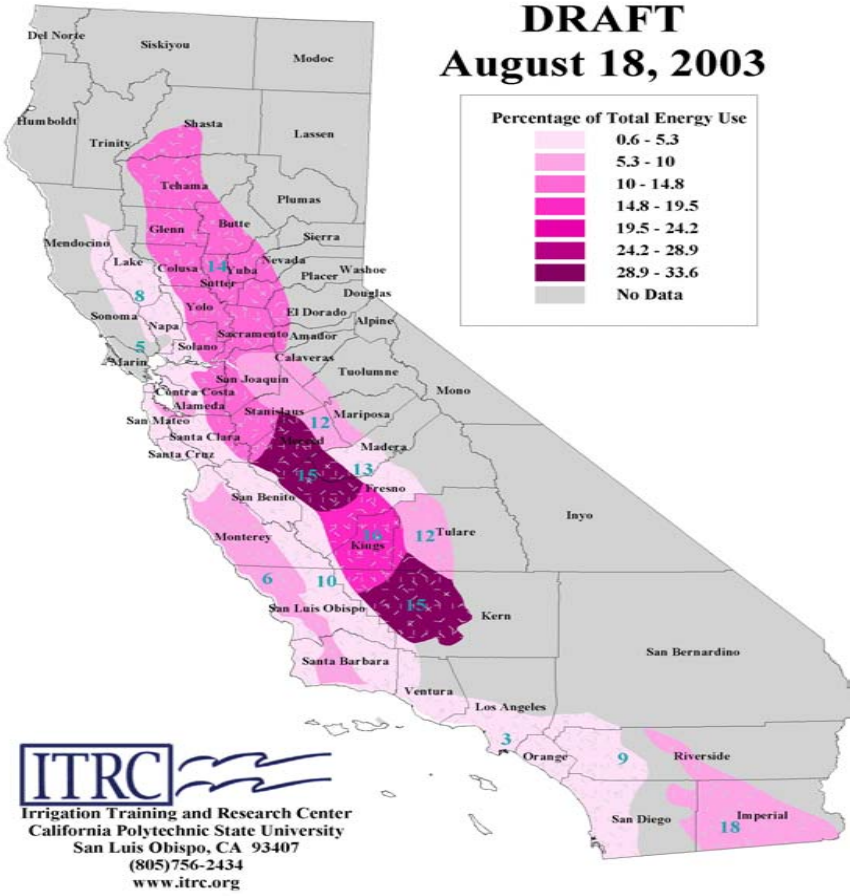


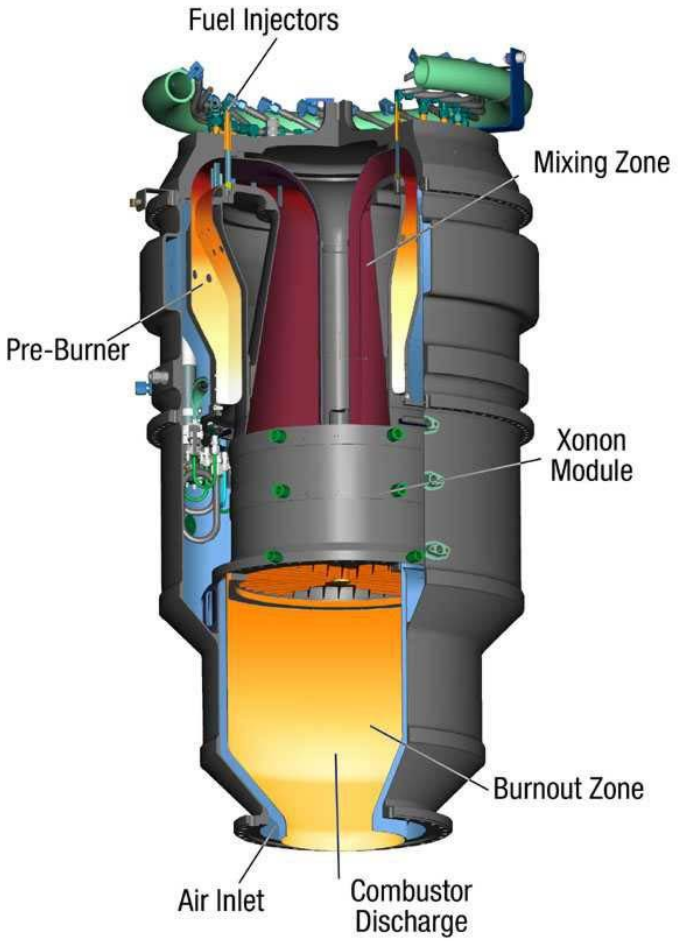
Figure: Shows where the majority of energy is used in the state for agricultural pumping.

Dry Cooling Spray Enhancement Reduces Water use Without Performance Penalty

- **Issue: Wet cooling requires enormous water consumption. Dry cooling has associated cost and performance barriers**
- **Project: Developed hybrid system: spray enhancement**
- **Benefits: Demonstrated the technical viability of spray enhancement; potential to recover 160,000 MWh/yr. state-wide of generating capacity; can be used to retrofit existing units**
- **Collaborators: EPRI, DWR**

Catalytica's Xonon Combustion System for Gas Turbines

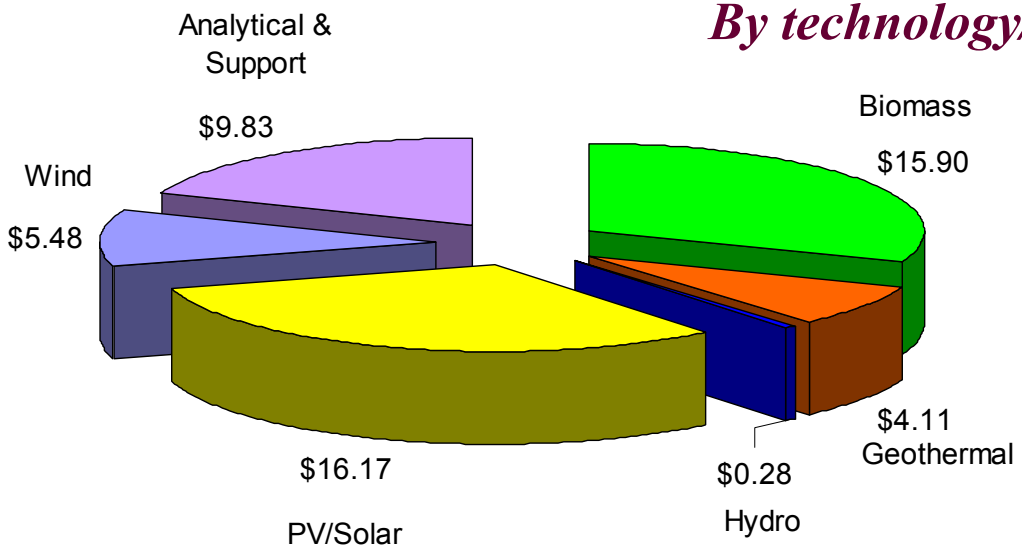
- California Air Resource Board pre-certification of Xonon.
- EPA's first Clean Air Excellence Award.
- Xonon lowers NO_x emissions without SCR and allows deployment of smaller turbines for DG by controlling combustion temperature to prevent NO_x formation.
- Now working with GE turbines



Catalytica's Xonon® catalytic combustor for use with a Kawasaki brand turbine

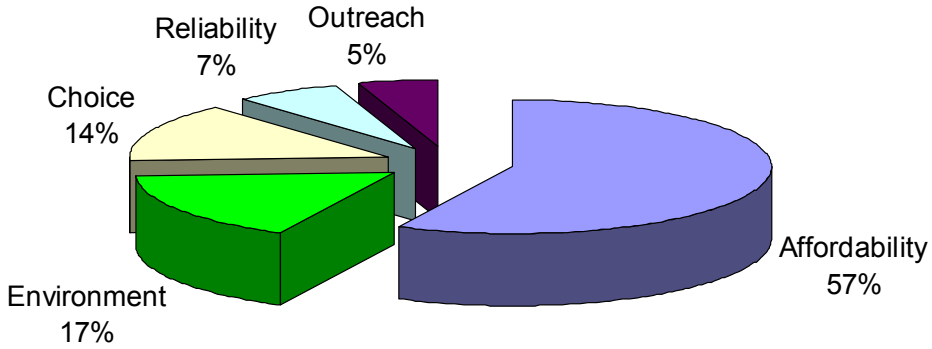
PIER Renewables Funding
(To Date)

By technology/activity



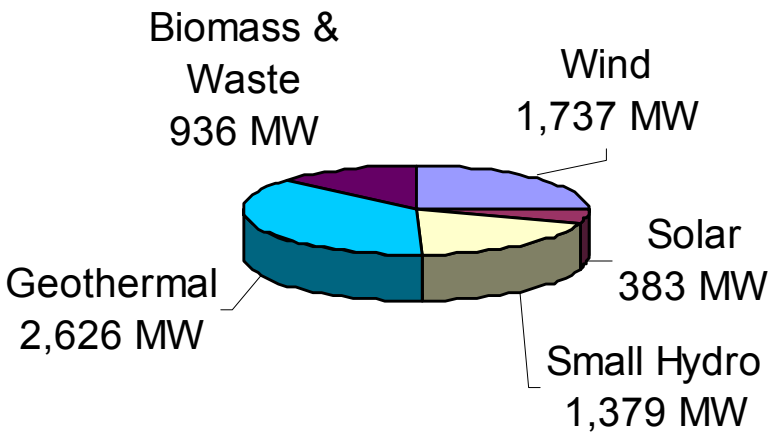
Funds in $millions (2002)

By issue addressed

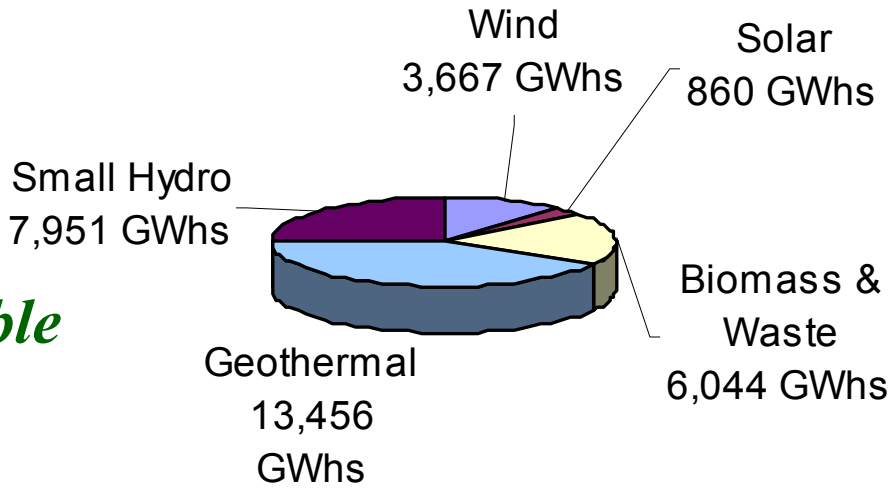


California Renewable Energy in 2000

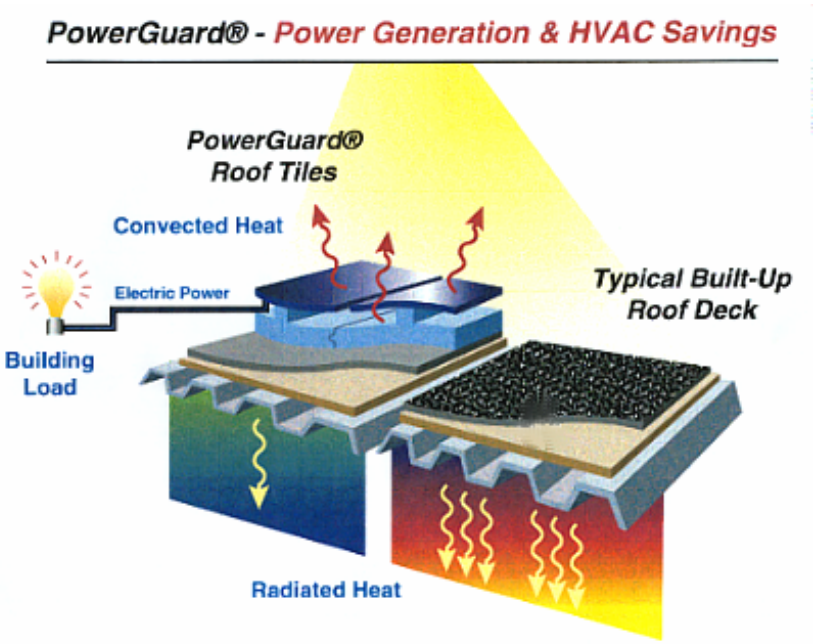
CA's In-State Renewable Capacity



CA's In-State Renewable Generation



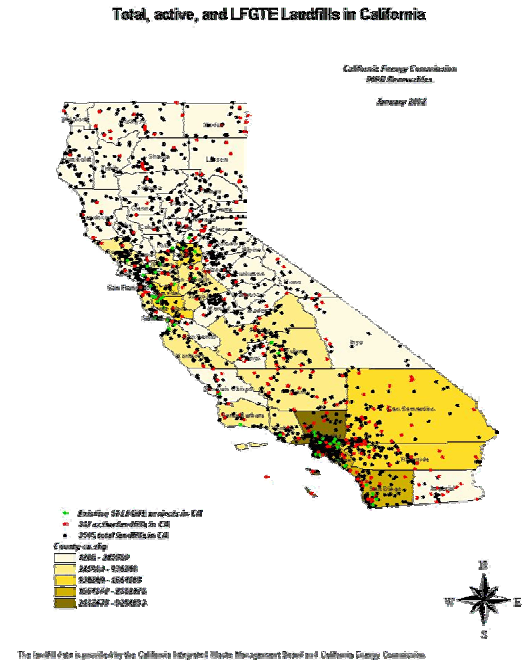
PowerLight's PowerGuard

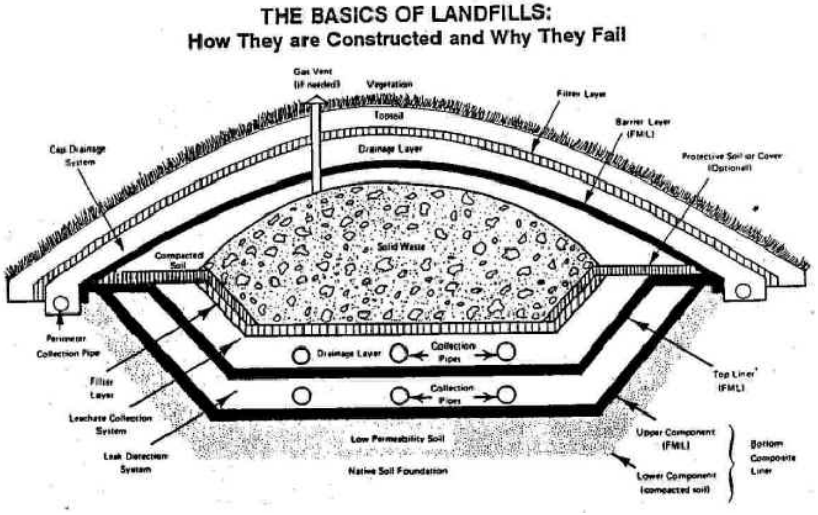


While California is known for its hot dry summers, that same solar resource provides a clean, safe and reliable way to generate electricity

PowerLight's insulated 30 year roof system reduces building air conditioning loads while it's PV surface generates electricity during hot and expensive peak summer hours

Yolo County's Bioreactor Landfill





Only 51 of California's 3000 landfills generate electricity from landfill gas. Up until this projects, it was too costly to generate electricity from many landfills.

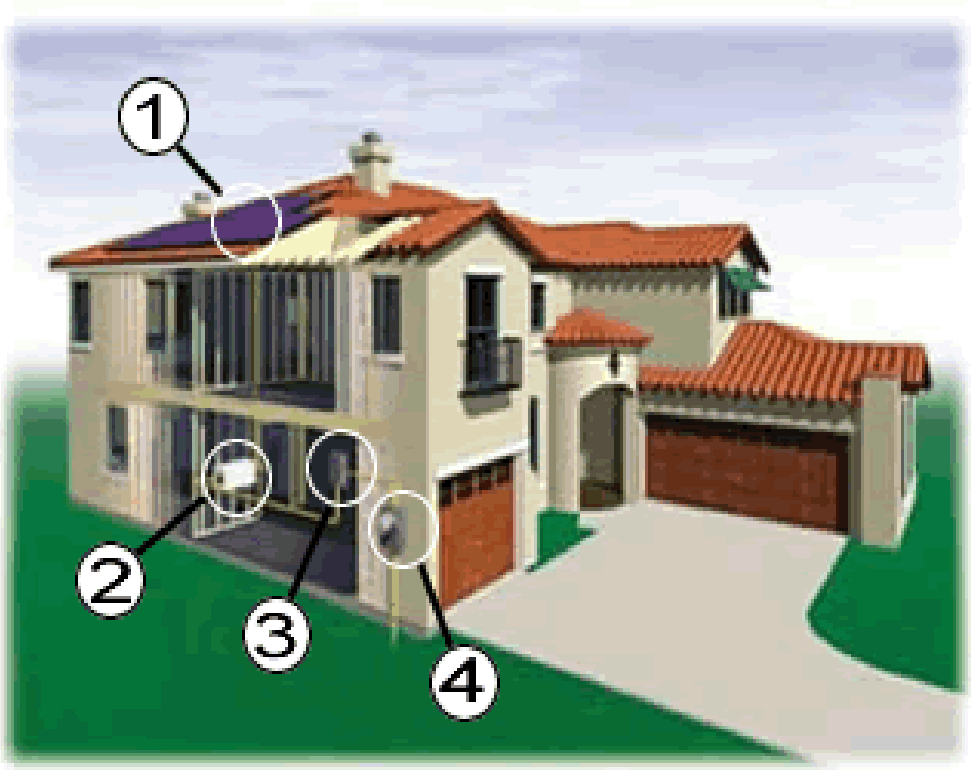
Yolo's bioreactor approach significantly increases gas generation making landfill electricity generation competitive.

Biomass Activities: Improving Costs and Performance, While Making Biomass Cleaner and More Responsive to Local Needs

- **Lowering High Costs**
  - Expanding capability to use lower cost fuels
  - Extending bioreactors that have high value to communities
- **Improving Performance**
  - Increasing co-firing and peaking capability
- **Making Biomass Cleaner**
  - Developing low emitting NOx technologies that will meet CARB's 2007 standards
  - Investigating ways to reduce groundwater and air quality impacts at landfills and dairies using advanced biogas systems
- **Increasing Responsiveness to Local Needs**
  - Developing small modular biomass technologies for local capacity/congestion issues
  - Expanding development/demonstrations on urban, forestry and agricultural residues that pose environmental problems

Potential New California Home with Efficiency and Integrated Solar

- **Translucent super-insulating power generating roof**
- **Inverter, Storage for TOU**
- **DC dedicated use**
- **Net metering**
- **Night Breeze cooling**
- **Grid-friendly appliances**
- **Lighting for California kitchens**
- **Community-based energy solutions**

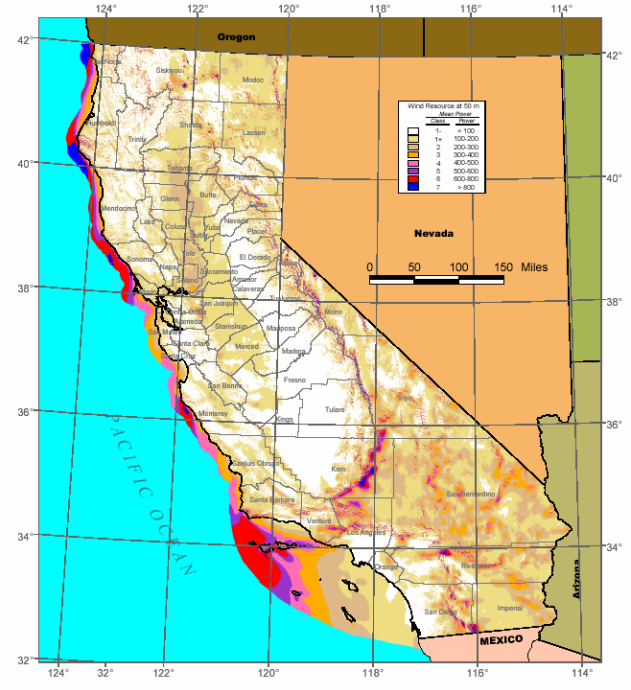


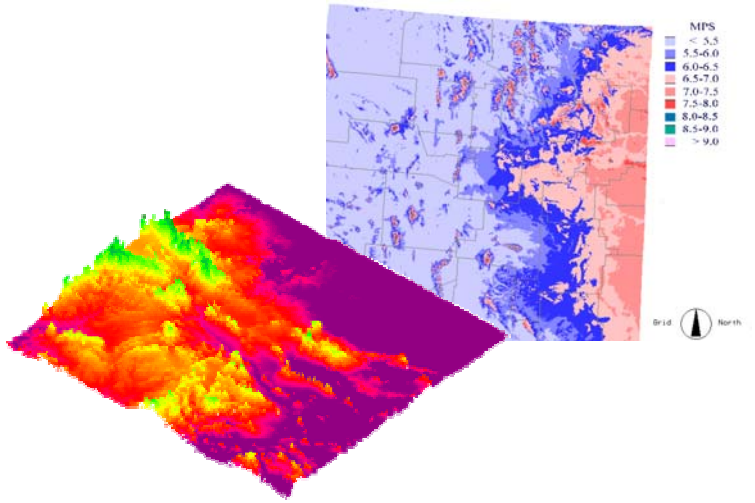
Developing Products to Better Integrate Renewables into the Grid

- High resolution wind maps
  - Updated and more comprehensive wind resource data that provided critical conclusions on wind development opportunities
- Wind performance reporting system
  - Updated performance and trends information
- Wind forecasting
  - Scheduling wind up to 48 hours ahead and helps Cal ISO with generation scheduling
- Clean power estimator
  - Estimating value of BIPV with efficiency options

Re-mapping & Validation

- Numerical modeling techniques coupled with meteorological expertise & field measurements
- Integrate GIS techniques for analysis & planning
- Couple tall tower and *remote sensing* data



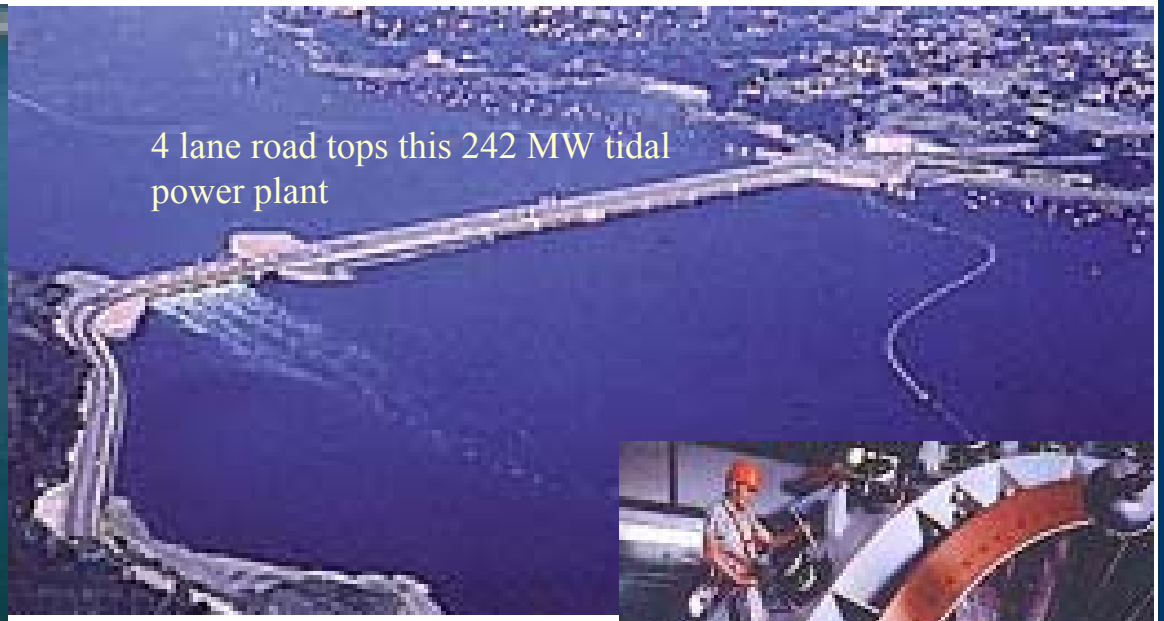


High resolution maps & GIS tools for planning wind project development

PIER has Recently Completed an Assessment of Ocean Energy Potential

- Focus on California
- Focus on wave energy

Tidal Energy:
Impoundment/Turbines

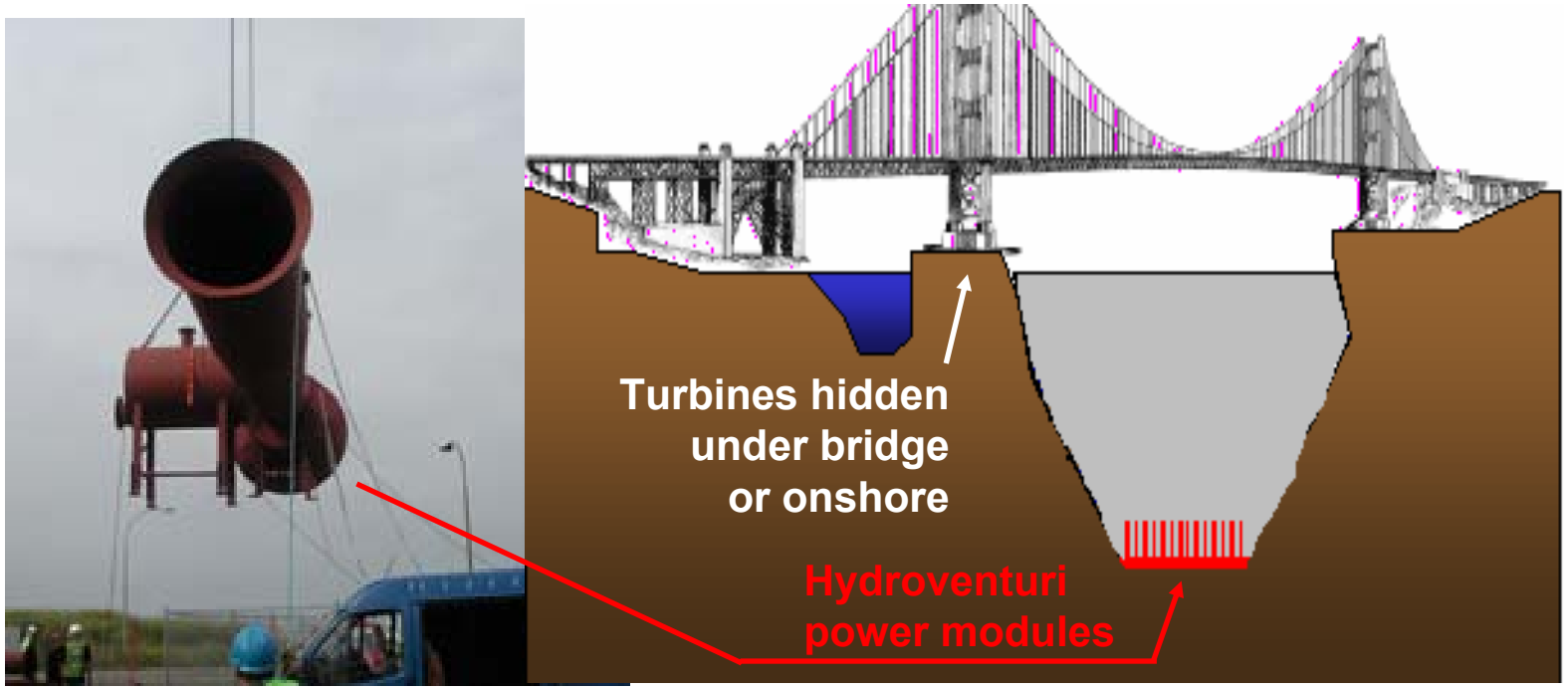


La Rance
Estuary, France
242 MW
Operating Since
1967

Tidal Demonstration
East River, New York City

Verdant Power received funding from NYSERDA and other participating state, federal, and private organizations for a prototype demonstration. FERC has issued a preliminary permit for the prototype tidal project.

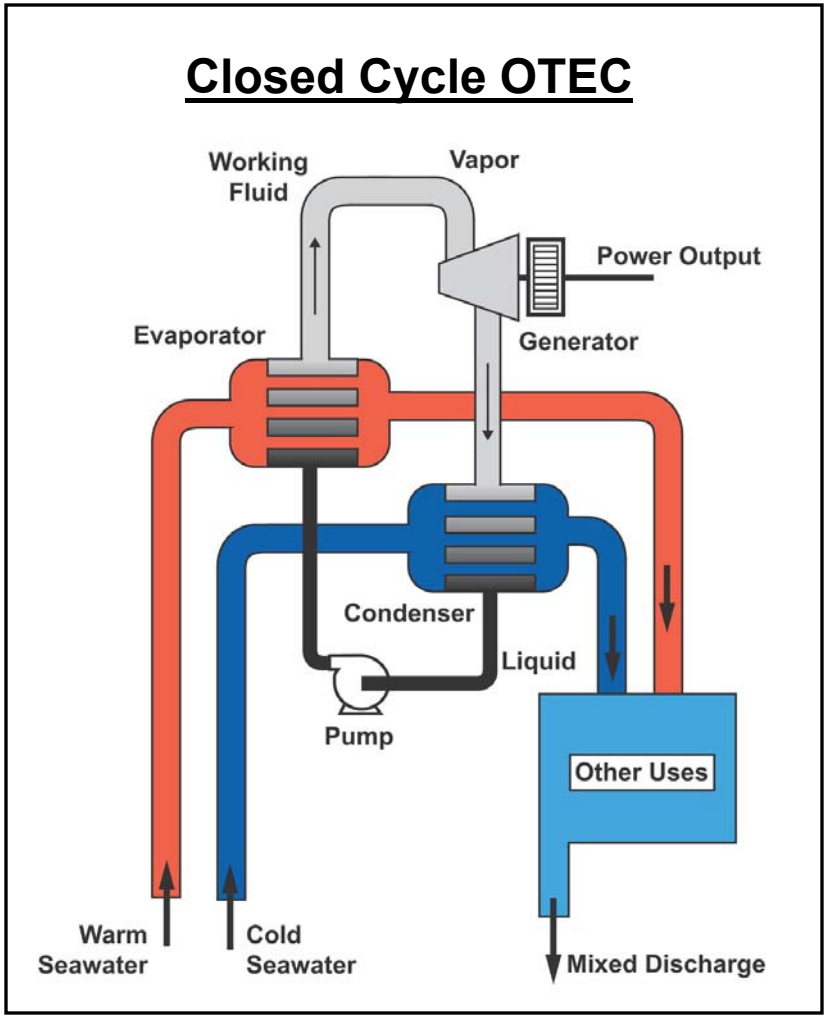
Proposed San Francisco Tidal Project



San Francisco Bay is one of top 10 tidal energy sites worldwide

- Total tidal energy in SF Bay ~ 2000 MW (> 2x peak power demand of San Francisco)
- 1 MW pilot project planned (future expansion possible)

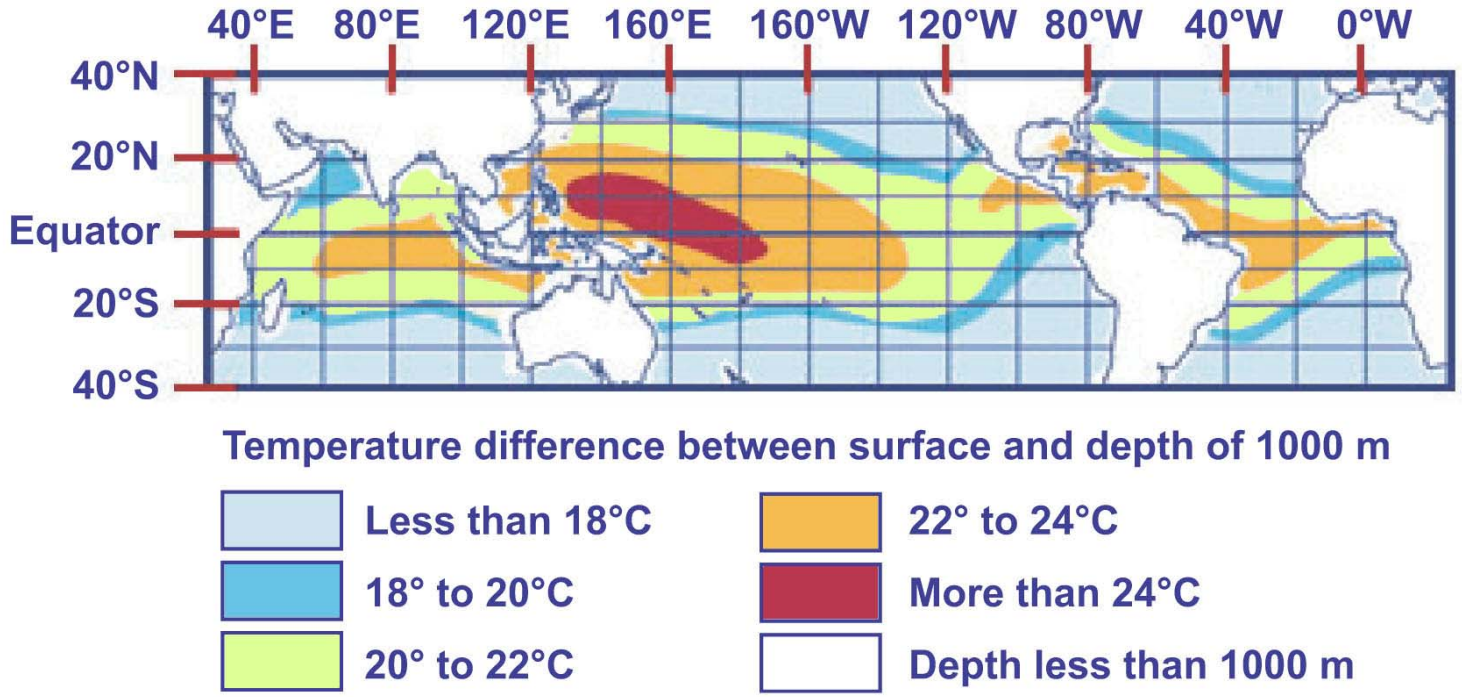
The Technologies:
Ocean Thermal Energy Conversion (OTEC)



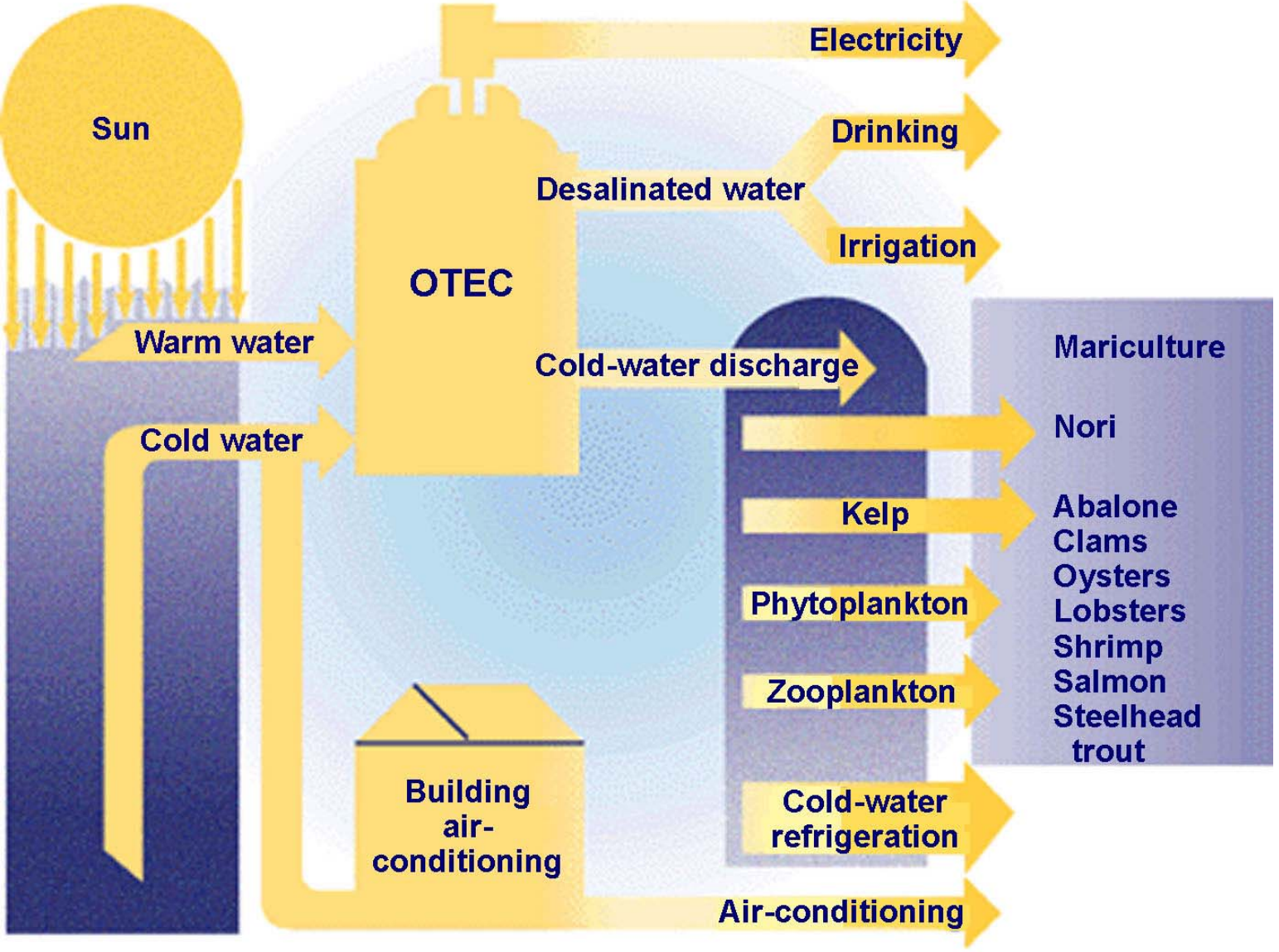
- Ocean's natural thermal gradient (warm surface waters, cold deep waters) drives power-producing cycle
- OTEC converts solar radiation to electric power
  - Tropical seas cover 60 million km^2 - world's largest solar collector
  - Solar radiation absorbed on average day equal in heat content to ~250 billion barrels of oil
- Three types of OTEC systems: open, closed, and hybrid

Global Ocean Thermal Gradient

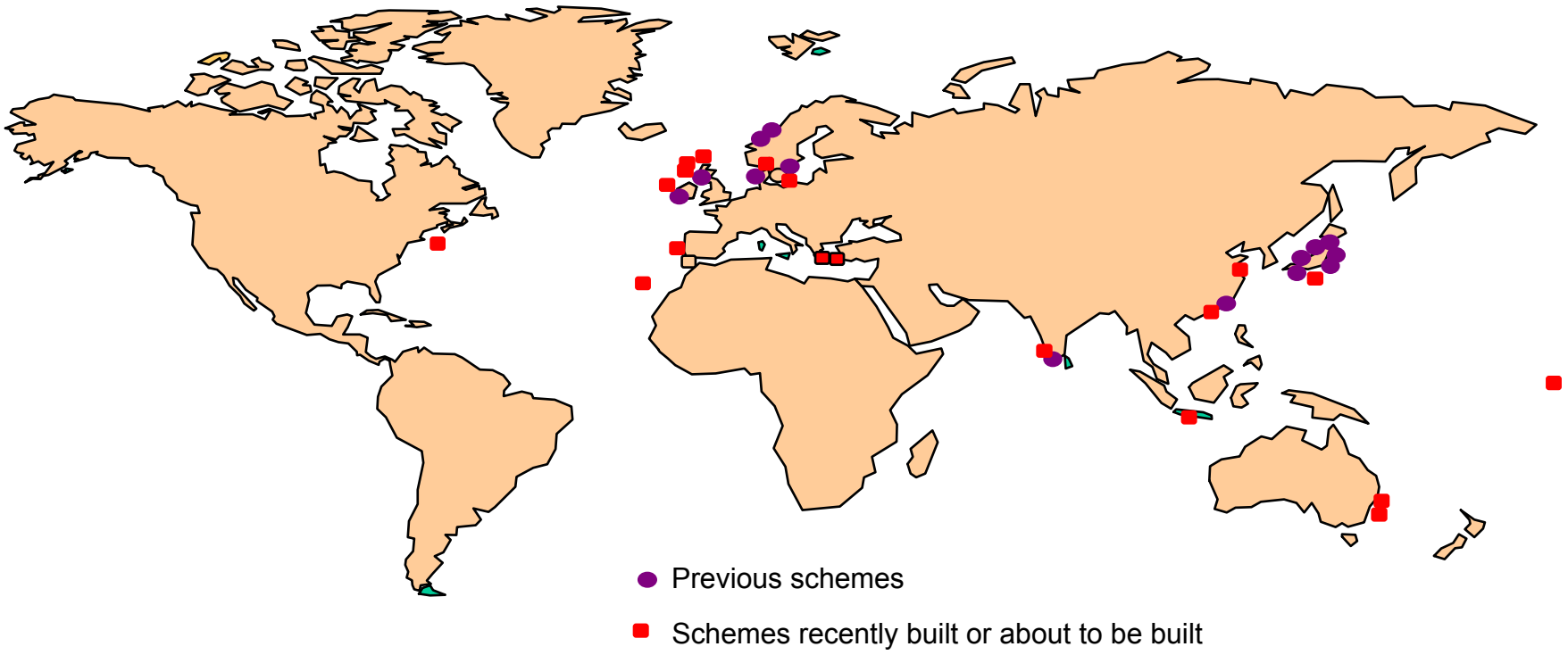
Temperature difference between warm surface water and cold deep water must be >20°C (36°F) for OTEC system to produce significant power



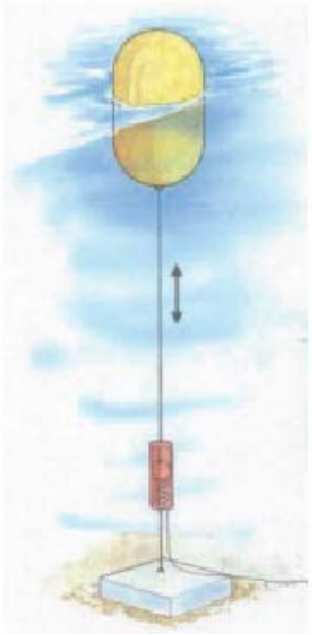
Other Uses for OTEC

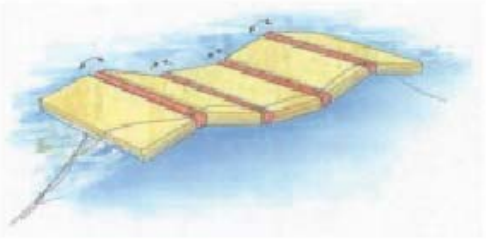


Worldwide Wave Energy Prototype Demonstration Sites



Buoyant Moored Devices



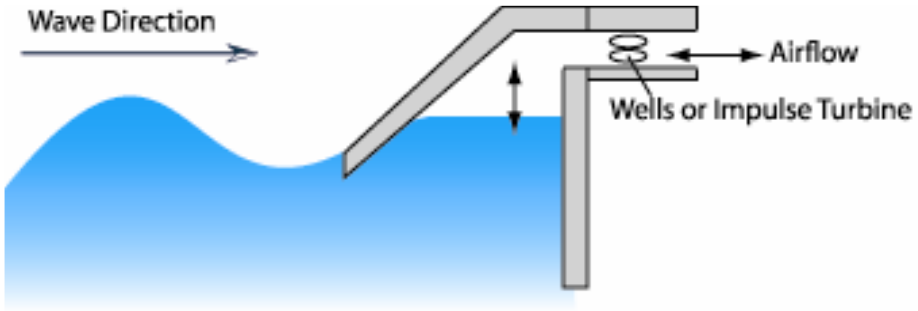


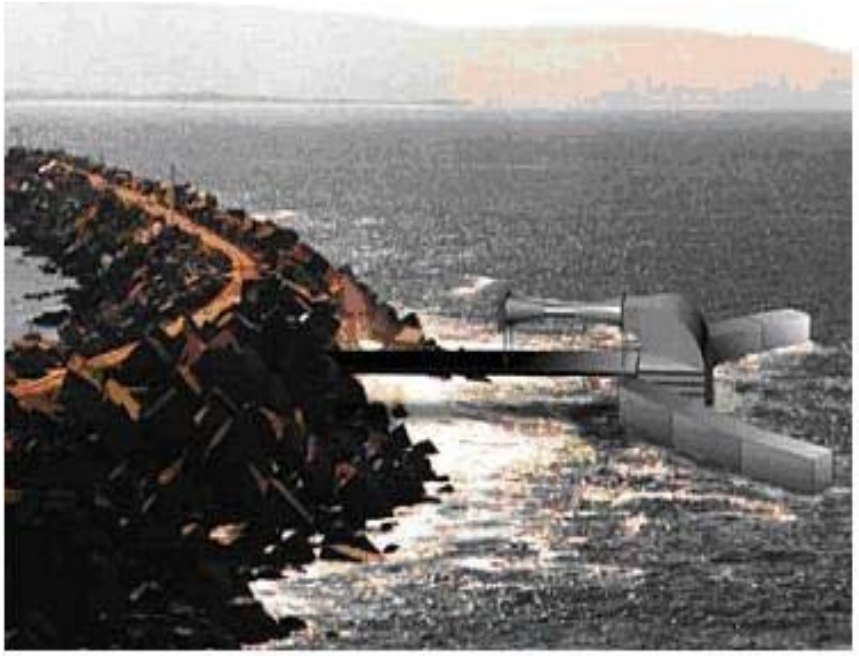
IPS Buoy Mark IV
(AquaEnergy Group Ltd, WA)

Power conversion:

Hydraulic compression system

Oscillating Water Column (OWC)



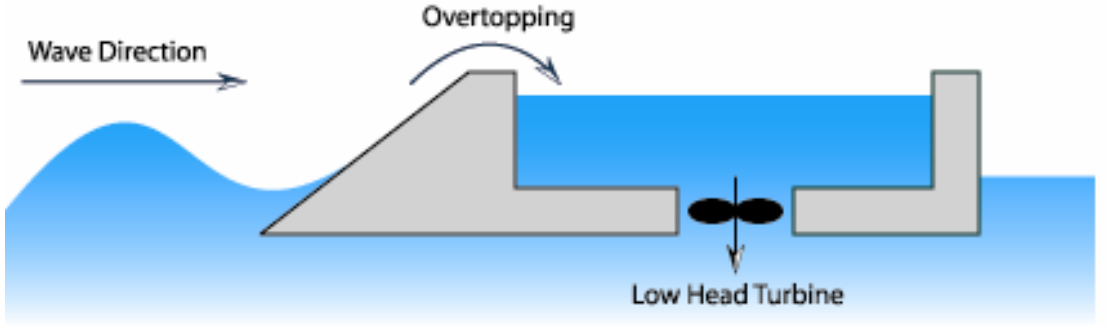


Energetech OWC
(Energetech, Australia)

Power conversion: Air turbine

WaveGen
Demonstration, UK

Overtopping Devices



Power conversion:

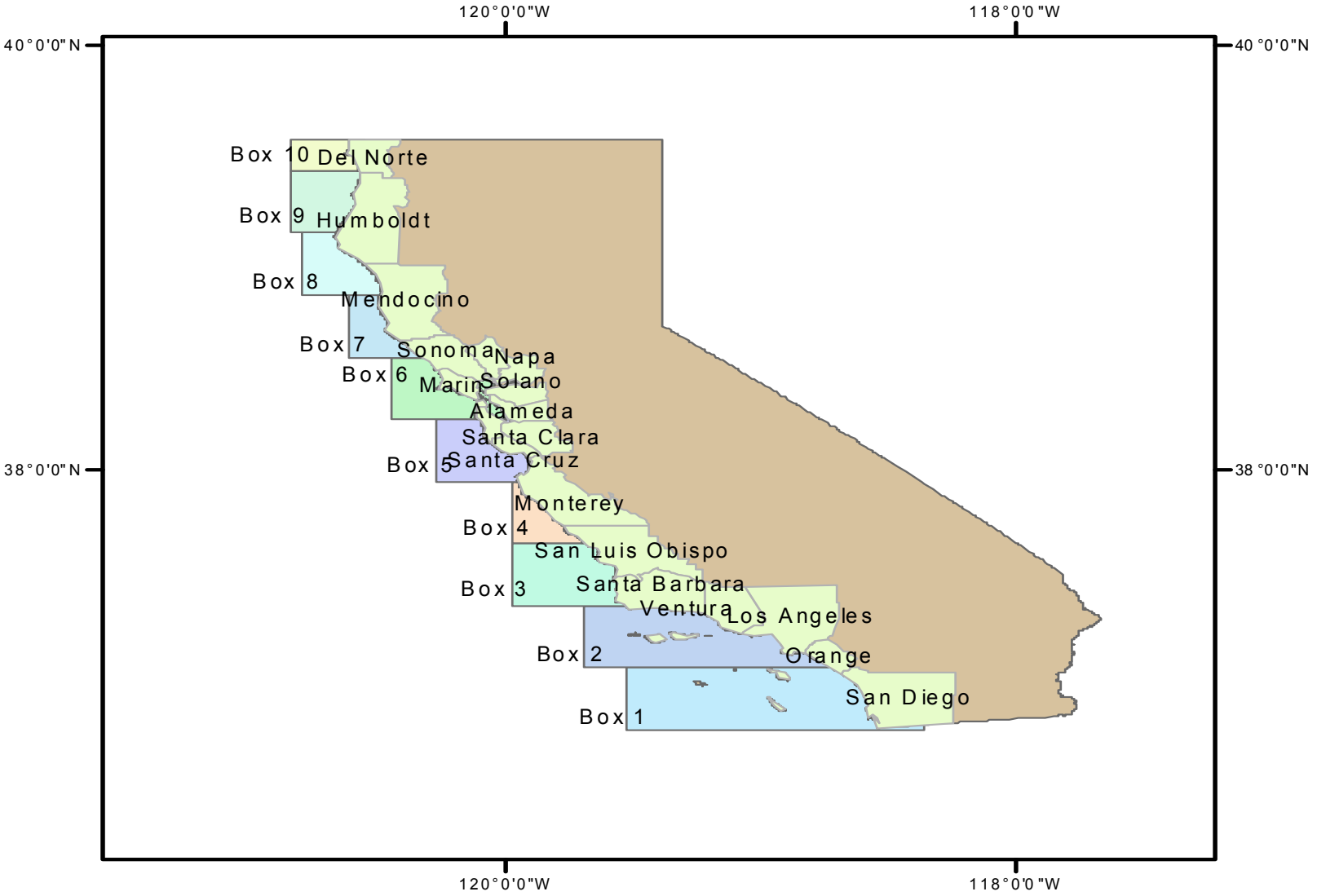
Low-head water turbine

Wave Dragon (Wave Dragon International, Denmark)

California Energy Commission
Wave Energy Resource Study

- Data sources
  - Coastal Information Data Program (CDIP), Scripps Institute of Oceanography
  - National Data Buoy Center (NDBC), NOAA
  - Wave Information Study (WIS) results
  - Pacific Ocean Reanalysis Wind 50-year time series
- Revealed:
  - CA has good wave energy resources close to shore because the ocean depth increases quickly westward
  - North of Point Conception is suited for electricity-generating WECs sited near-shore or offshore
  - South of Point Conception wave energy is dispersed because of the shadowing effect of the Channel Islands

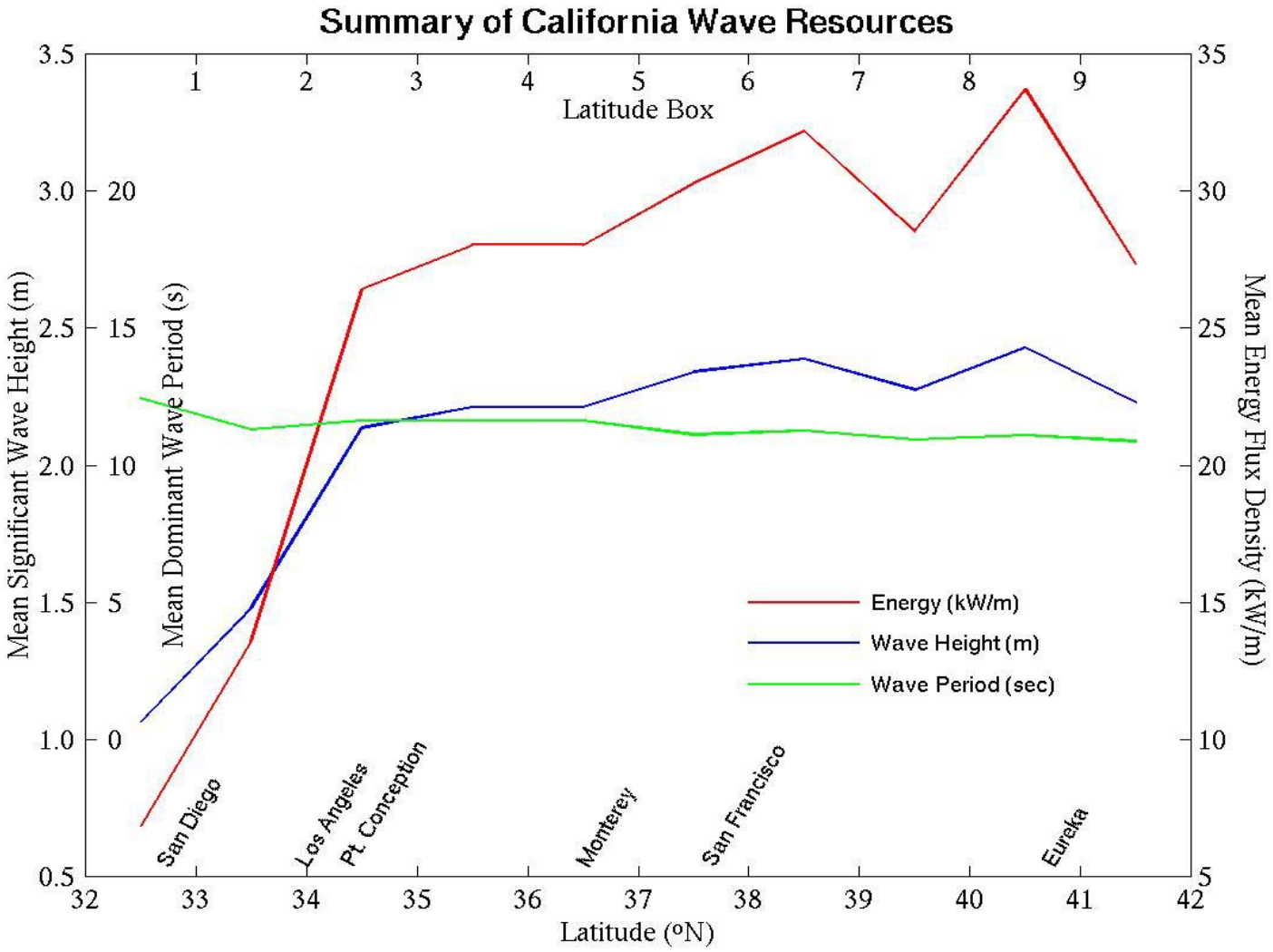
Resource Evaluation: Ten One-Degree Latitude Cells



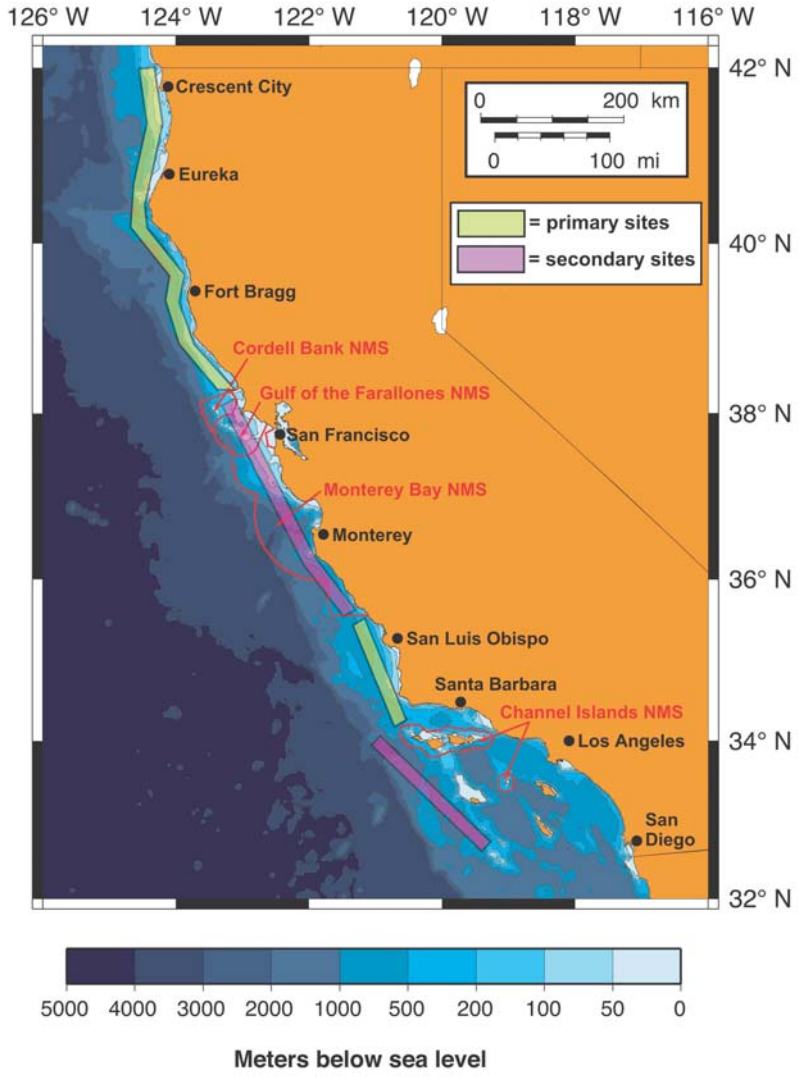
Wave Energy Density Varies Widely Off Coastline at Point Conception from N-S

E

W



California Wave Energy Resources



Primary Sites

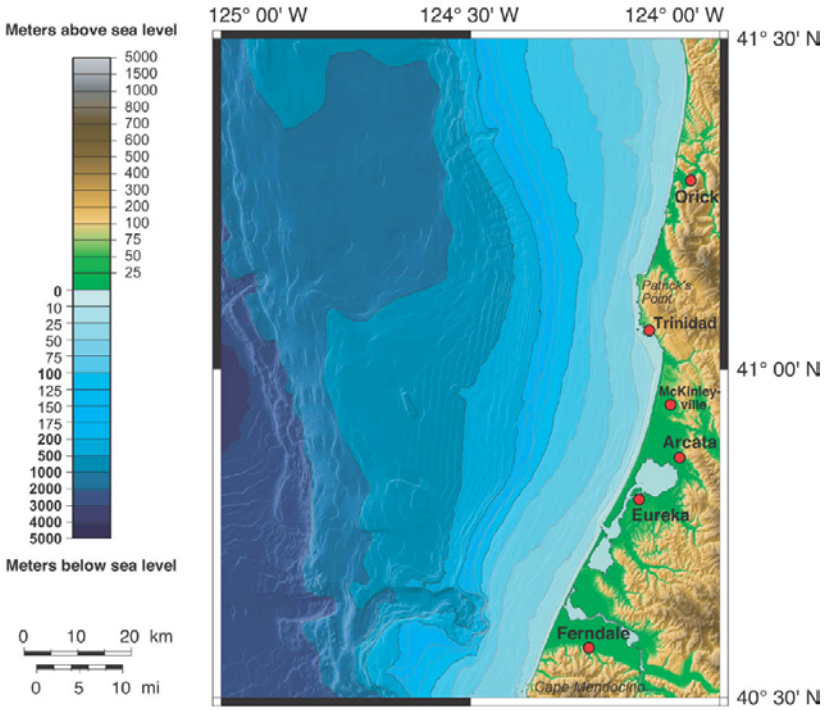
- Excellent wave conditions and deep water (> 50 m) within 10 miles from shore
- Reasonable permitting process

Secondary sites

- Sites located further offshore due to wave shadowing effects (e.g., Channel Islands in Southern California)
- Anticipated permitting difficulties (e.g., marine sanctuaries)

Wave Statistics for Individual Cells

Cell 9: Northern Humboldt County



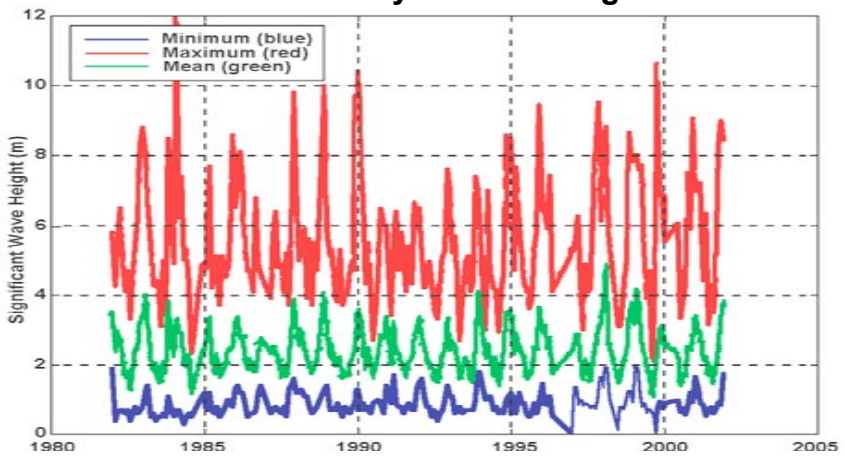
Mean Statistics

Significant wave height: 2.46 m (SD = 1.13)

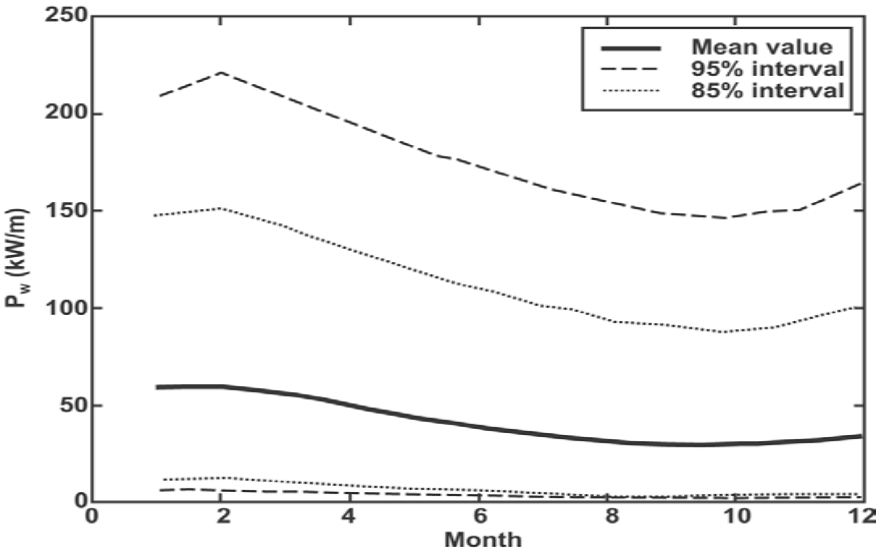
Dominant wave period: 11.14 s (SD = 3.41)

Wave power density: 33.71 kW/m

Interannual Variability of Wave Height for Box 9

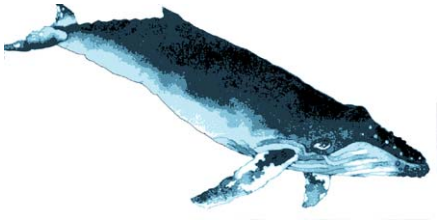


Seasonal Variability of Wave Power for Box 9



Projected Costs of Produced Electricity are Highly Uncertain

- Very little short-term operational experience available
- Wave energy conversion technologies are in the development and testing stage
- Offshore is much more expensive than onshore
- Economic improvements likely to result from
  - Increased capacity factors based on improved tuning algorithms
  - Improved reliability and resulting lower O&M costs
  - Improved maintenance strategies
  - Standards for operation and maintenance should lower insurance cost
  - Economies of scale and learning by doing



Environmental and Permitting Issues

Environmental Impacts Must Be Better Characterized

Activities affiliated with WEC

- Directional drilling through shoreline
- Laying/burying power transmission cables
- Setting down anchors on seabed
- Drilling into seabed for heavy-uplift anchors
- Operation and maintenance activities
- Attenuation of wave energy during power generation

Potential impacts

- Visual impacts in scenic areas
- Disruption of fish and marine mammal migration
- Perturbation of sedimentation patterns
- Disturbance of seabed ecosystem
- Navigation hazards

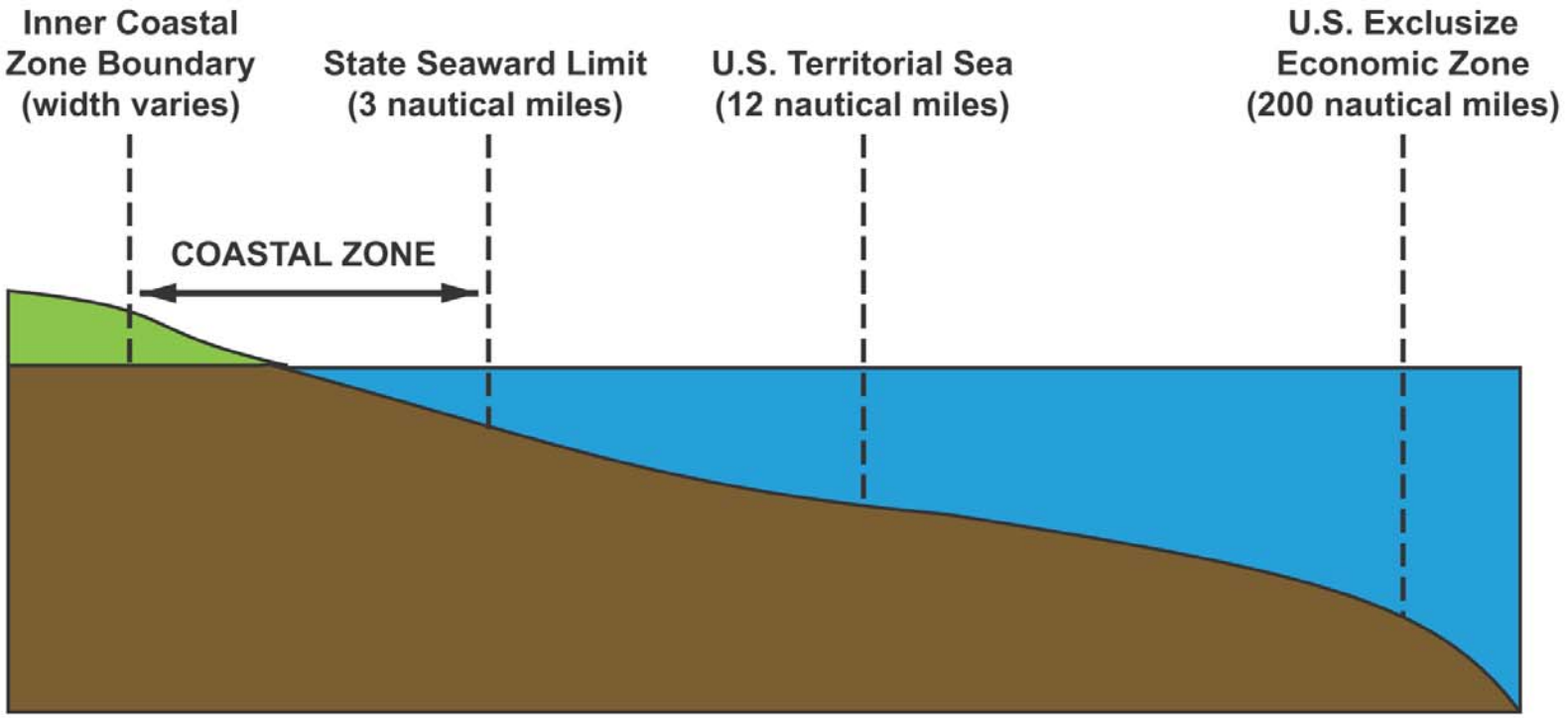
Environmental Impacts

Hypothesis: WEC power generation has low environmental impact relative to other renewable and fossil energy sources

- Most significant impacts occur during construction/installation (i.e., short-lived)
- Low visual impact for low-lying, offshore devices
- No major disturbances anticipated to fish and marine mammal migrations
- No emissions and/or discharges

Maritime Boundaries

Coastal development involves federal, state and local jurisdictions



Permitting: Relevant Agencies

Federal

- U.S. Army Corps of Engineers (USACE)
- U.S. Coast Guard
- U.S. Environmental Protection Agency (EPA)
- Federal Energy Regulatory Commission (FERC)
- U.S. Fish and Wildlife Service
- National Marine Fisheries Service

State

- California Coastal Commission
- California State Lands Commission
- California State Water Resources Control Board
- Regional Water Quality Control Boards
- California Department of Fish and Game

** Local county/city government agencies may also be involved

Permitting: Relevant Regulations

Federal

- River and Harbors Act
- Title 33 -- Navigation and Navigable Waters
- Clean Water Act
- Marine Protection, Research and Sanctuaries Act
- Federal Power Act
- Coastal Zone Management Act
- Submerged Lands Act
- Endangered Species Act
- Fish and Wildlife Coordination Act
- National Environmental Policy Act (NEPA)

State

- Porter-Cologne Water Quality Control Act
- California Coastal Act
- California State Lands Act
- California Endangered Species Act
- California Environmental Quality Act (CEQA)

The New DOE Initiative on Regional Carbon Sequestration is an Example of Federal/State/Lab/Industry/NGO Interaction

- States: CA, OR, WA, NV, AZ, AK
- Labs: LLNL, LBNL, NETL
- Industry: BP, Shell, Kinder-Morgan, ….
- Consultants: EPRI, ARI, Nexant, SFA Pacific,…
- Public Outreach: Science Systems, San Francisco, NRDC, Universities

Climate Change and Carbon Management: Efficiency, Decarbonization, Sequestration

- Improve understanding of impacts (economic, biological, energy implications) and develop adaptation strategies relative to CA
- Current portfolio implements Environmental RD&D program
  - Improved monitoring and modeling (Scripps Institute)
  - Carbon Sequestration (West Coast Regional Carbon Sequestration Partnership)
- CDWR, CDFA, LBNL, Winrock, EPRI, US Forest, DOE, EPA, CALFED, NSF, NOAA, Kearny
- AK, WA, OR, NV, AZ
- Implications for Northern California
  - Site for terrestrial sequestration
  - Ocean sequestration conundrum

Some Closing Thoughts on Ocean Energy Potential and Issues

- The potential for oceans as an energy resource cannot be ignored
- Considerable national and international funding will be required to prove economics
- Oceans will also be investigated as a Carbon Sink
- CEC/PIER has limited resources
  - Can partner with USG
  - Must focus on near-term projects

California's R&D Activities are Critical in Supporting State Energy Policy

- California's energy policy and initiatives will continue to differ from Federal policies
- PIER R&D initiatives have, and will continue to, affect Federal energy program decisions
- Program is designed to address both ratepayer needs and legislative interests

Stream of technologies to market will allow California to economically achieve policy goals

Driving to a Sustainable Future: The "E"s are Linked

- Environment
- Energy
- Economics
- Equity
- Education